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GEOLOGY OF THE LA VENTA BADLANDS COLOMBIA, SOUTH AMERICA

BY

ROBERT W. FIELDS

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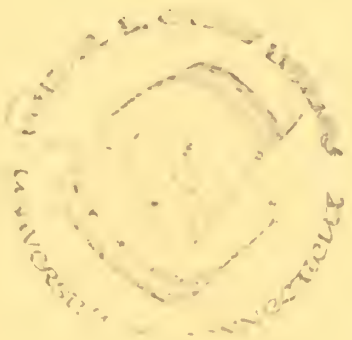

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GEOLOGY OF THE LA VENTA BADLANDS COLOMBIA, SOUTH AMERICA

BY

ROBERT W. FIELDS

(A contribution from the University of California Museum of Paleontology)

ABSTRACT

Sedimentary rocks in the La Venta badlands range in age from Jura-Triassic to Quaternary. The La Venta beds are apparently part of Hettner's Honda formation, here called Honda group, and are dated as late Miocene on the basis of fossil mammals. The deposits vary in lithology, and alternating periods of flooding and drying caused formation of red beds and "torpedo-shaped" concretions. The sediments were derived from nearby sources to the south and west. They have been slightly faulted and gently folded by contemporaneous and postdepositional tectonic activity.

INTRODUCTION

THIS PAPER describes the geology of the La Venta badlands northeast of Villavieja in the upper Magdalena River Basin, Department of Huila, Colombia, South America. The sediments exposed in this region are part of a complex depositional sequence named the Honda formation by Hettner (1892). The stratigraphic section in the La Venta area comprises more than 700 meters of conglomerates, sandstones, and silty claystones.

Several interesting lithologic and structural features are present, the most interesting being large, elongate, torpedo-shaped concretions, which in certain areas lend a striking appearance to the topography (pl. 38, *c;* pl. 39, *a*).

Faulting has played a part in the history of the La Venta region and its effects are clearly displayed. Minor faults are present west of Cerro Gordo, and an unusual hinge fault in the El Dinde area (map 2) demonstrates faulting during the time of deposition.

Each stratigraphic unit has been given an informal name, e.g., El Libano Sands and Gravels, Cerbatana Gravels and Clays, Upper Red Bed, and so on, for convenience in keeping fossil assemblages in stratigraphic sequence, but are not intended as formal rock-stratigraphic terms (Stirton, 1951*a*, p. 316). Much more widespread and detailed geologic work is necessary before formal stratigraphic terminology can be applied.

Little is known of the continental Tertiary stratigraphy of northern South America. Several petroleum companies have done reconnaissance work within the Tertiary deposits but detailed investigation has been neglected. Attention was first drawn to the region, specifically to the upper Magdalena River Basin of Colombia, in 1939, when R. A. Stirton received two specimens of fossil mammals from William Effinger of the Richmond Petroleum Company. The specimens had been collected on the west side of the Magdalena River near Guacireo, between Neiva and Aipe, Department of Huila.

In 1944, Dr. Stirton, aided by a John Simon Guggenheim Fellowship, led an expedition into the upper Magdalena River Basin in search of additional fossils, primarily to seek evidence of intercontinental dispersal of terrestrial vertebrates

between North and South America. The Colombian government, through its Servicio Geológico Nacional, coöperated by supplying personnel and equipment. On this first expedition many interesting and significant fossils were collected but there was insufficient time for geologic mapping. The second expedition, January to July, 1949, in which I had the pleasure of participating, was sponsored jointly by the University of California Associates in Tropical Biogeography and the Servicio Geológico de Colombia. The Servicio assigned a geologist, Diego Henao-Londoño, and topographer, Israel Osario, to the expedition. It was the purpose of this second expedition to augment the earlier collection with as much material as could be found and to establish an efficient means of keeping the fossil localities in correct stratigraphic order. Topographic base maps were not available for most parts of the Magdalena Basin, so before any geology could be worked out, such maps had to be prepared. As each topographic sheet was completed Henao and I mapped the geology of the area it covered. Ultimately these sheets were organized into a topographic and geologic map of the area between Cerro Gordo and the Upper Red Bed (map 2).

To complete the study, selected sections were measured and sampled. As a result of the geologic mapping, the sampling of sections, and the subsequent examination of the sediments in the laboratory, this report presents geologic data pertinent to the understanding of the stratigraphic, paleontologic, and paleoecologic factors represented by the La Venta fauna and the sediments in which it is found. It also presents specific data relative to the several faunal papers already published or in preparation.

In figure 2 the University of California Museum of Paleontology locality numbers and locality names for the La Venta materials are listed and the localities are shown in their proper stratigraphic position on the appropriate columnar section. The approximate geographic position of each locality can be found by referring to the column reference letters on the geologic map (map 2).

A note on the stratigraphy and geologic section from Cerro Gordo to Las Mesitas was published by Royo y Gómez (1946), and a preliminary report on the continental stratigraphy and vertebrate paleontology of Colombia was written by Stirton (1953*b*). A cross-section—Cerro Gordo through the Upper Red Bed—prepared by me was published in Stirton, 1951*a;* it is reproduced here (fig. 1). A preliminary faunal list was made by D. E. Savage (1951*b*). Other elements of the fauna reported on are the Sirenia (Reinhart, 1951); Chiroptera (Savage, 1951*a*); Primates (Stirton, 1951*a*), (Stirton and Savage, 1951); Interatheriidae (Stirton, 1953*a*), and Rodentia (Fields, 1957).

Acknowledgments

I am particularly grateful to Dr. R. A. Stirton for constant encouragement and inspiration. It was through his efforts that I was able to conduct my research in Colombia. I also owe a debt of gratitude to the University of California Associates in Tropical Biogeography and the Servicio Geológico Nacional de Colombia, joint sponsors of the second expedition. I wish to make special acknowledgment of the cordial coöperation of Sr. Diego Henao-Londõno, colleague on the expedition, for without his help the mapping could not have been completed.

Thanks are also due Dr. C. L. Camp and Dr. Howel Williams, who offered many

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The following colleagues gave valuable assistance in the preparation of maps and in other phases of the problem: Dr. D. E. Savage, Dr. T. Downs, Dr. W. Langston Jr., and Mr. K. H. Kilmer. To my wife, Charlotte G. Fields, must go a special note of appreciation for constant encouragement and inspiration and for her excellent help in the preparation of the manuscript.

Methods

All linear and vertical measurements are given in meters. Base maps were constructed by normal plane-table methods on a scale of 1 to 5,000 meters and a contour interval of 2 meters. The finished map was redrawn to smaller scale and a contour interval of 10 meters. Stratigraphic sections were measured by standard plane-table, hand-level, or Brunton compass and tape methods. The choice of instruments depended upon the local topography and the detail required in any part of the section being measured. The generalized cross-section 0–0′–0″ (fig. 1) was taken directly from the original geologic map and then reduced for convenience in handling.

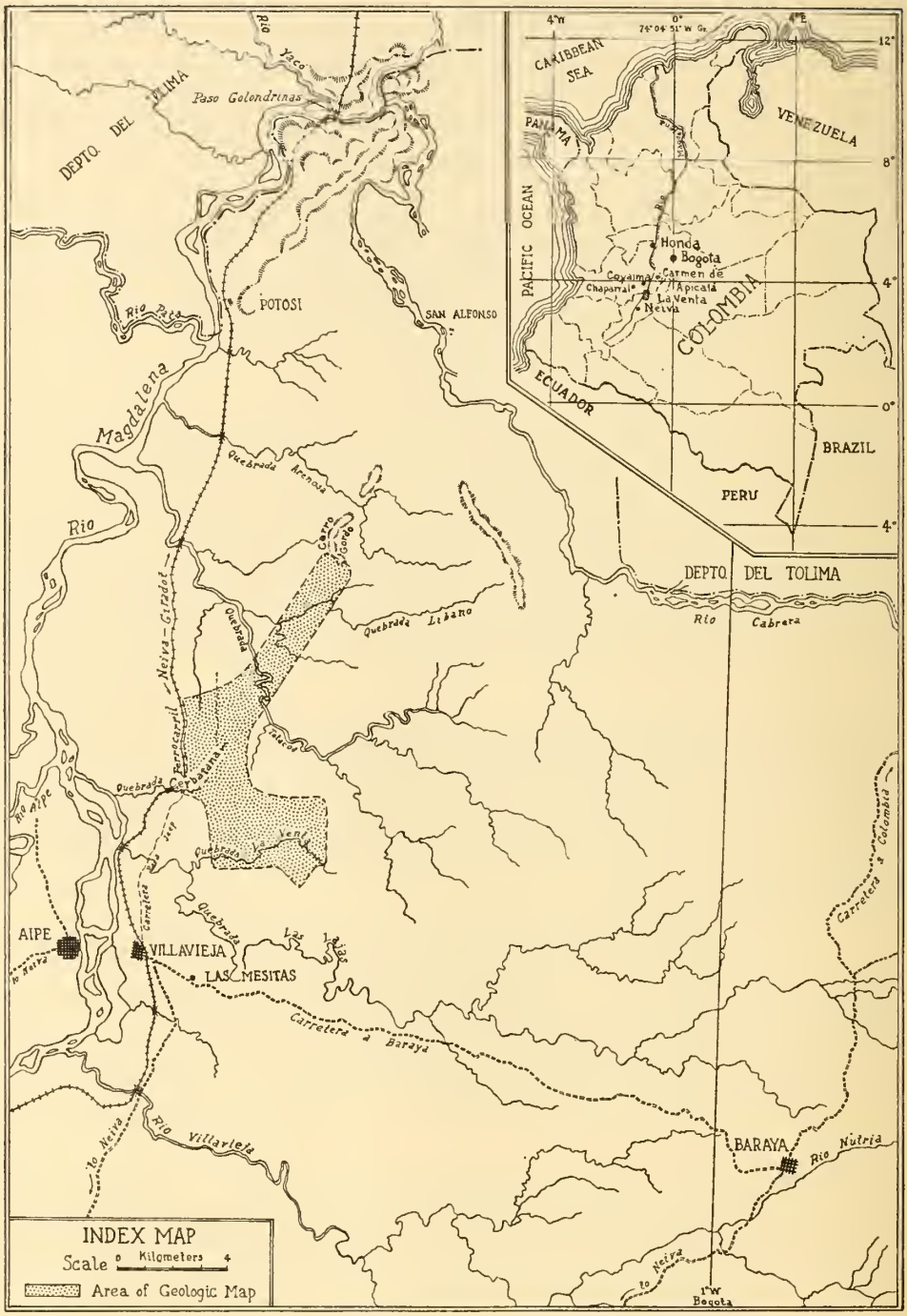
Mechanical and mineral analyses of the sedimentary rock samples were made by observation of disrupted samples under a binocular microscope. Grain size was determined by comparison with a micrometer grid and a set of graded sediment samples based on the standard Wentworth grade scale. Roundness classes were established by comparison with the chart supplied in Pettijohn (1949, fig. 24), and minerals were identified by observation. Cementing materials were identified by standard chemical procedures.

Location and Nature of the La Venta Badlands

The La Venta badlands lie in the upper Magdalena Basin, northeast of the village of Villavieja in the northern part of the Department of Huila. The La Venta area is defined as the region lying within the drainage patterns of the Quebrada Tatacoa, Quebrada Libano, Quebrada La Venta and the lower reaches of the Quebrada Las Lajas. Its geographical position is 3° 19′ north latitude and 75° 8′ west longitude.

The present work, except for necessary reference to regional features, is limited to detailed consideration of the area immediately around the Quebrada La Venta drainage and the area between the Quebrada Cerbatana drainage and Cerro Gordo (map 1).

The La Venta badlands have an average elevation of 460 meters above sea level. Maximum relief in the mapped area is 104 meters: the altitude of Cerro Gordo, the highest point, is 518 meters, and that of the lowest, the stream bed of the lower reaches of Quebrada Tatacoa, 414 meters, above sea level. West of the Neiva-Giradot railroad and continuing south along the west side of the mapped area are a



Map 1. Index map of the northwestern part of the Department of Huila and its relationship to the area covered by the geologic map.

number of conglomerate-capped mesas that rise to an average elevation of 500 meters (pl. 40, *b*). These isolated mesas and a larger plateau-like feature south of the Quebrada Las Lajas are erosional remnants of a former widespread piedmont plain that originated from the surrounding mountains, especially those to the west, as a series of coalescing alluvial fans. The valley floor, in which the Magdalena River is entrenched, has a width of 15 to 20 kilometers and lies between the flanks of the central and eastern cordilleras. In places it is as much as 150 meters lower than the tablelands and mesas. All drainage in the region is tributary to the Magdalena River, and most streams, except the Rio Cabrera to the northeast and the Rio Villavieja and Quebrada Las Lajas to the south, may be considered as intermittent, since they flow perennially only where fed by springs. A prominent escarpment, developed in the Cerbatana Gravels and Clays, separates the La Venta and Cerbatana drainage from that of Quebrada Tatacoa and Quebrada Libano and diverts the main course of the Tatacoa northward.

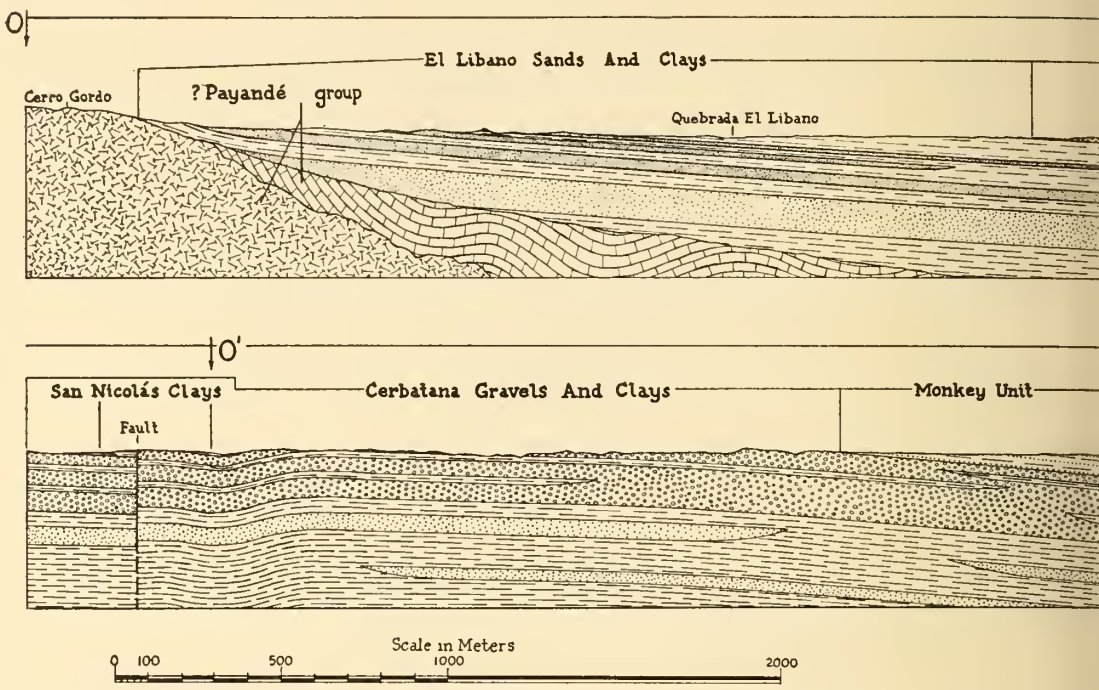
The water supply for humans and stock is, on the whole, meager. Water in running streams is unfit for human consumption unless sterilized. Fortunately, throughout most of the region, water suitable for human use can be obtained from springs issuing from sandstone outcrops. Along the course of Quebrada Tatacoa and Quebrada Libano, water can be obtained from subsurface flow in the sandy beds of these streams.

The climate of the La Venta region is semiarid: the average annual rainfall is about 40 inches, less than one-fifth of the average in most parts of the middle and lower Magdalena valleys. There are two wet seasons: April and May constitute the spring rainy season, and October, November, and part of December the fall rainy season. Much of the rainfall takes place as localized torrential downpours during thunderstorms. The abundance of bare rock surfaces and the consequent rapid runoff swells the usually dry streams into impassable torrents so heavily charged with sediments that they take on the character of mudflows. Frequently storms produce floods capable of considerable damage to property.

Because of the lack of soil and vegetation rock exposures abound everywhere. Like most badland territories where rains are torrential and erosion extreme, this area is characterized by escarpments, gullies, and mesas whose walls have rock exposures that are continuous for many kilometers. The geologist is thus afforded an excellent opportunity to trace beds, study their changes, and evaluate geologic data.

The flora is that typical of desert areas. Scattered guava trees and other small shrubs are common along stream courses, but in general the badlands are barren. Mesquite, cat's-claw, croton, and several varieties of cactus are common but scattered. Grasses are not abundant, except in marginal areas along stream courses.

The La Venta badlands are accessible from Villavieja by jeep or heavy-duty field car via the Cerbatana area and northward as far as Quebrada Tatacoa during the dry seasons (map 1). The drainage areas of Quebrada La Venta, Quebrada Libano, and the upper reaches of Quebrada Tatacoa are accessible only on horseback or on foot. During the rainy seasons saddle and pack animals are needed for transportation throughout the entire region.



STRATIGRAPHY

The sedimentary rocks exposed in the La Venta region range in age from Jura-Triassic to Quaternary. Within the mapped area their total thickness is more than 730 meters. The oldest rocks crop out on Cerro Gordo and progressively younger rocks are exposed toward the south and west. The Jura-Triassic sequence is a complex of igneous rocks and marine strata but the Tertiary section is entirely continental.

The areal distribution of the stratigraphic units in the La Venta region is shown in map 2. Variations in thickness and stratigraphic relationships of the various units are shown in figures 1 and 2.

Jura-Triassic

?Payandé group

The name ?Payandé formation has been applied to that part of the pre-Cretaceous section in the upper Magdalena River Basin that unconformably overlies the basement complex of the Central Cordillera. This section is discussed by Trumpy (1943), who separates the section into pre-Payandé Red Beds, Payandé formation, and post-Payandé Red Beds. Because this sequence is poorly understood, a broader term, such as "group," would probably serve the purpose better. The name ?Payandé group is thus proposed to include the three-fold pre-Cretaceous section described by Trumpy: a basal sequence of red beds and porphyritic volcanics, the fossiliferous cherty limestone sequence exposed near the town of Payandé that has been designated the type of the Payandé formation, and the overlying transi-

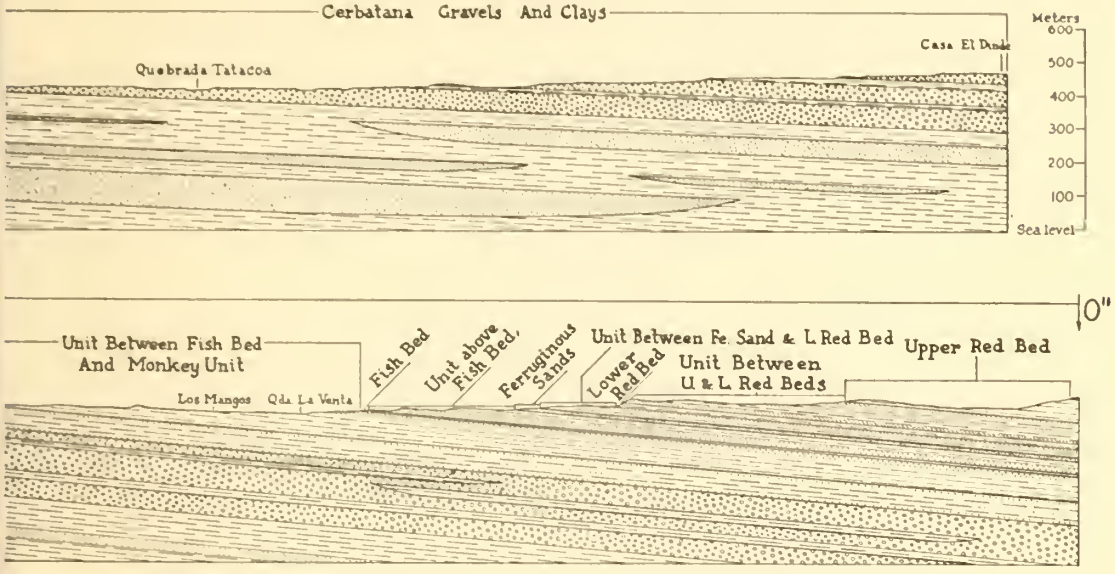


Figure 1. Generalized cross-section from Cerro Gordo to the Upper Red Bed showing the stratigraphic units in which the La Venta faunal remains were found. The reference points 0–0′–0″ refer to the section line on the geologic map.

tional sequence of porphyritic flows, tuffs, and volcanic breccias that are unconformably overlapped by Lower Cretaceous beds.

The ?Payandé group is the oldest rock unit exposed in the La Venta badlands and crops out on Cerro Gordo at the northern margin of the region here described (map 2). Two types of brecciated igneous rock were observed. The most abundant type is a porphyritic andesite in which phenocrysts of andesine, averaging about 10 millimeters in length, constitute about 50 per cent of the volume. Small subhedral pyroxene, hornblende, biotite, and magnetite crystals are present but form no more than 2 per cent of the bulk. The groundmass is cryptocrystalline, dark-gray on fresh surfaces and reddish-brown on weathered exposures. Light-gray lenticular inclusions of unknown composition are present, the largest measuring 9.5 millimeters across. Calcite is abundant as fracture fillings.

Whether these rocks are flows or are dike and sill intrusions is uncertain. They may be part of a shallow laccolith. There is no parallel arrangement of the phenocrysts to indicate direction of flow.

The second type of igneous rock is a reddish-brown pyroxene andesite. Colorless andesine phenocrysts, 2 to 3 millimeters in length, occur sporadically in the groundmass, forming no more than 1 per cent of the rock. The groundmass is microcrystalline with small subhedral crystals of pyroxene. Small cavities lined with crystalline material are probably vesicles, and calcite is present as a secondary fracture-filling. This rock is probably a flow.

Several large igneous bodies are exposed around Coyaima (map 1). On one of these, Cerro de Viana, I collected samples similar to those collected at Cerro Gordo. At Coyaima, however, the nature of the microcrystalline igneous material could

be seen. Here it is probably extrusive, as flow-banding is apparent and both vesicular and scoriaceous structures are present. Individual flows were quite fluid, for they occur as rather thin, even sheets.

North of the mapped area some outcrops of this complex contain sandy limestone. It remains questionable, however, whether this complex can be correlated with the section at Payandé. Lithologically it shows certain similarities to the section discussed by Trumpy (1943); hence, for the present the Cerro Gordo complex is questionably referred to the ?Payandé group.

Late Miocene

HONDA GROUP

The term Honda was used originally by Hettner (1892) as a formational name for a sequence of conglomerates, sands, and clays that crop out in the area around the city of Honda, Tolima. The type locality has been ascertained by Butler (1942) to be the Cordillera San Antonio, east of Honda. Much confusion has centered around this name in the Magdalena Basin. Butler, in reviewing the literature, notes that the names Barzalosa formation (Scheibe, 1922), Giradot formation (Weishe, 1926) and Real series (Wheeler, 1935) have been applied, in toto or in part, to Hettner's original Honda formation. Butler (1942, p. 808) concludes: "It seems proper to use Hettner's term Honda on the basis of priority and present widespread use but to consider the strata to comprise a geological series, rather than a formation, inasmuch as future detailed work will undoubtedly show that subdivisions into formations will be practical." Stirton (1953 *a*, *b*) followed Butler but proposed that the "series" designation, being a time-stratigraphic term, be changed to "group," a rock-stratigraphic term, in accordance with good nomenclatural procedures. Butler pointed out that the Honda sediments are separable into an upper and lower Honda. The upper Honda, +2,400 meters thick, is characterized by mica-pyroxene andesite, glassy feldspar, abundant hornblende, and slightly less abundant black metallic minerals, together with conglomerates containing many dacite, andesite, black chert, and quartz pebbles. He also mentions occasional tuffaceous beds and concretionary sandstones. The lower Honda, ±1,600 meters thick, is characterized by the absence or rarity of the foregoing features. Butler deferred a detailed subdivision of the sequence until more specific knowledge of the unit and its "intra" and "inter" relationships is available.

The geology of the Magdalena Basin is, in effect, still within the stage of reconnaissance. Nevertheless, in view of the arguments brought forth by Butler, I choose to follow him in broadening the rank of this rock unit. I also agree with Stirton that the name Honda group, a rock-stratigraphic term, should be applied to this lithogenetic sequence. For the present the Honda group must remain undifferentiated. Later elaboration will determine whether the group contains two or more formations.

The Honda group is exposed throughout the La Venta badlands except along stream courses, where it is buried under Quaternary alluvium, and on mesas, where it is capped by the Pleistocene Mesa Conglomerate. The Honda group in this area is approximately 700 meters thick. Usually, it consists of well-bedded gray, greenish-gray, buff, "pepper-speckled" sandstones; pebble and gravel conglomerates; and reddish, mottled red, brown, buff, green, greenish-gray, and gray siltstones

and claystones of varying thickness and succession. Calcium carbonate is the usual cement but is not always present. Bedding ranges from thin to massive with abundant occurrences of cross-bedded and torrentially bedded strata.

In the lower part of the section siltstones are the most common but sandstones are also present. In the middle of the section, pebble, gravel, and cobble conglomerates predominate. However, coarse-grained sandstones and several siltstones and claystones are interbedded in the conglomerates. The upper third of the section is a variable succession of sandstones, siltstones, claystones, and mudstones. It is characterized by two red beds, the uppermost of which is 70 meters thick.

STRATIGRAPHY OF THE LA VENTA BADLANDS

Pleistocene		Mesa Conglomerate ± 20 meters
	~~ Disconformity ~~	
Miocene	Las Mesitas Sands and Clays Upper Red Bed Unit Between Upper and Lower Red Beds Lower Red Bed Unit Between Ferruginous Sands and Lower Red Bed Ferruginous Sands Unit Above Fish Bed Fish Bed Unit Below Fish Bed Monkey Unit Cerbatana Gravels and Clays (Including San Nicolás Clays) El Libano Sands and Clays	Honda group ± 704 meters
	~~ Unconformity ~~	
Jura-Triassic		?Payandé group + 100 meters

El Libano Sands and Clays

(Figs. 1 and 2, sec. J; map 2)

The El Libano Sands and Clays are the oldest sediments of the Honda group exposed in the area. They crop out around the fringe of Cerro Gordo and overlap the porphyritic andesites of the ?Payandé group. The upper contact of this unit parallels the south fork of Quebrada Libano.

The El Libano unit is composed of calcareous siltstones with interbedded calcareous sandstones and mudstones. The siltstones are generally darker than those in the upper parts of the La Venta section. On casual observation the siltstones appear rather massive but detailed inspection shows variable but distinct bedding. Individual layers may be only 5 or 10 centimeters thick but some measure as much as 3 meters. Grains are rounded to subangular and range from about $\frac{1}{3}$ millimeter to below $\frac{1}{256}$ millimeter in size (table 1). Quartz is the main constituent. Feldspars, fresh amphiboles, and metallic minerals form less than 10 per cent of the identifiable fraction (table 2). The beds are poorly indurated by calcareous cement.

TABLE 1

MECHANICAL ANALYSIS OF SEDIMENTS: EL LIBANO TO UPPER RED BED

Sample	Grain roundness	Cement	Millimeters						
			2 to 1	1 to 1/2	1/2 to 1/4	1/4 to 1/8	1/8 to 1/16	1/16 to 1/256	Below 1/256
El Libano	subrounded to subangular	calcareous	....	....	2.0	10.0	32.0	50.0	6.0
El Libano	rounded to subangular	none	....	40.0	40.0	15.0	5.0	....	....
El Libano	subrounded to subangular	calcareous	....	....	....	5.0	10.0	80.0	5.0
Base of San Nicolás	rounded	calcareous	5.0	25.0	45.0	15.0	10.0	....	....
Camp Cerbatana	subrounded to subangular	calcareous	....	....	1.0	4.0	10.0	80.0	5.0
Base of Monkey Unit	rounded to subangular	calcareous	1.0	15.0	30.0	22.0	20.0	12.0	....
Interathere Loc.–Monkey Unit	rounded	none	....	....	....	5.0	10.0	25.0	60.0
Lone Tree Loc.–Monkey Unit	rounded to subrounded	none	....	....	1.0	4.0	25.0	30.0	40.0
Toxodont Loc.–Monkey Unit	anular to subangular	calcareous	2.0	40.0	55.0	3.0	....	....	....
Toxodont Loc.–Monkey Unit	rounded to subrounded	calcareous	....	....	10.0	25.0	55.0	10.0	....
Top of Monkey Unit	rounded to subangular	calcareous	....	2.0	25.0	40.0	30.0	3.0	....
Unit below Fish Bed	rounded	calcareous	....	....	....	2.0	25.0	70.0	3.0
Fish Bed	rounded	calcareous	....	....	....	1.0	2.0	12.0	85.0
Between Fish Bed and Ferruginous Sandstone	rounded	calcareous	....	....	....	10.0	15.0	35.0	40.0
Ferruginous Sandstone	subrounded to angular	limonite	....	30.0	45.0	20.0	4.0	1.0	....
Lower Red Bed	rounded	none	....	....	3.0	15.0	30.0	45.0	7.0
Upper Red Bed	rounded	none	....	....	....	....	5.0	10.0	85.0

TABLE 2

MINERAL ANALYSIS OF SEDIMENTS: EL LIBANO TO UPPER RED BED

Sample	Quartz (rock and crystal)	Feldspar (all)	Hornblende	Mica (Muscovite and Biotite)	Magnetite and Ilmenite	Rock Fragments	Clay minerals	Indeterminate	Remarks
El Libano	85.0	4.0	1.0	1.0	1.0	....	3.0	5.0	.....
El Libano	65.0	15.0	4.0	4.0	3.0	4.0	....	5.0	.....
El Libano	75.0	15.0	2.0	3.0	2.0	....	....	3.0	concretionary
Base of San Nicolás	58.0	14.5	10.0	6.0	1.5	5.0	....	5.0	concretionary
Camp Cerbatana	76.0	....	1.0	4.0	2.0	....	2.0	15.0	.....
Base of Monkey Unit	83.0	5.0	1.0	2.0	3.0	1.0	1.0	4.0	concretionary
Interathere Loc.–Monkey Unit	63.0	....	2.0	3.0	trace	....	27.0	5.0	.....
Lone Tree Loc.–Monkey Unit	71.0	5.0	2.0	5.0	2.0	....	10.0	5.0	.....
Toxodont Loc.–Monkey Unit	82.0	5.0	4.0	3.0	4.0	2.0	....	....	.....
Toxodont Loc.–Monkey Unit	85.0	4.0	1.5	2.5	3.0	....	....	4.0	.....
Top of Monkey Unit	83.0	8.0	1.0	3.0	2.0	....	....	3.0	.....
Unit below Fish Bed	88.0	....	trace	4.0	2.0	....	trace	6.0	.....
Fish Bed	60.0	....	trace	....	trace	....	38.0	2.0	.....
Between Fish Bed and Ferruginous Sandstone	79.0	....	2.0	3.5	.5	....	....	15.0	.....
Ferruginous Sandstone	47.0	30.0	10.0	7.0	4.0	....	....	2.0	limonite cement
Lower Red Bed	65.0	5.0	1.0	2.0	.5	....	24.0	2.5	.....
Upper Red Bed	62.0	....	....	3.0	trace	....	35.0	....	bentonitic

Weathered slopes are littered with small, rounded calcareous nodules. Fracture fillings and veins of calcite are common in the siltstone beds.

The interbedded sandstones occur as discontinuous lenses and tongues. Some can be traced for many kilometers but usually they lens in and out in a distance of one to two kilometers or less along strike (map 2). They vary greatly in thickness (fig. 2) and are usually massive, although some show large-scale current-bedding. Individual grains range from $\frac{1}{10}$ to 1 millimeter in size but more than 70 per cent of the grains fall between $\frac{1}{4}$ and 1 millimeter. Most grains are rounded or subrounded but a few are subangular (table 1). Quartz predominates but there is a high percentage of feldspar fragments. Amphiboles, metallic minerals, and rock fragments are also abundant, giving the beds a pepper-speckled appearance (table 2). Pebbles are common and occur in pockets or along bedding planes and show imbricate structure in response to current flow.

SECTION OF EL LIBANO SANDS AND CLAYS BETWEEN CERRO GORDO AND QUEBRADA LIBANO

CERBATANA GRAVELS AND CLAYS

EL LIBANO SANDS AND CLAYS

	Meters
1. Siltstone; even-bedded, beds average 50 centimeters; light-brown to greenish-gray; calcite veins, small rounded concretions litter weathered slopes	8.0
2. Sandstone; current-bedded; dull greenish-gray, pepper-speckled; coarse- to medium-grained, pebbles locally abundant; ledge forming; lenticular	4.0
3. Siltstone; like no. 1, vertebrate fossils	3.0
4. Sandstone; massive-bedded, foreset-bedded with oriented pebbles locally; buff to gray; coarse- to medium-grained; limy; poorly indurated; upper limit with rounded concretions up to 40 mm. in diameter; ledge forming	5.0
5. Siltsone; even-bedded in upper portion, lower limits unevenly bedded, layers up to 3 meters thick; dark-brown to greenish-gray; calcareous with veins, fracture fillings and small calcareous siltstone nodules, sandy in places; soft, weathers into badlands	20.0
6. Sandstone; large-scale diagonal and convex inclined bedding with small lenses of pebble and granule conglomerate, silts, and mudstone scattered through entire thickness; light-brown to gray; coarse-grained, individual grains rounded to subangular; no cement except in uppermost layers where pebble concretions and calcareous silt nodules are present, prominent ledge former	22.0
7. Siltstone; interbedded with muddy and sandy layers; siltstone beds reddish-brown, average 1 meter; gray sandy and reddish muddy beds usually thin; calcareous with calcite fracture fillings, veins, and small round to irregular siltstone and calcite concretions; weathers into bedlands	17.0
8. Sandstone; diagonal and convex inclined current-bedding; several large lenses of pebble and granule conglomerate; gray to buff; very coarse-grained, arkosic, no cement; ledge forming	30.0
9. Siltstone, sandy mudstone; lower strata thick bedded, grading to thin bedded in upper part; reddish-brown alternating with greenish- or bluish-gray; calcareous with small irregular concretions; soft, weathers into badlands	50.0
10. Sandstone with prominent conglomerate lenses; sands current-bedded; coarse- to medium-grained, arkosic; ledge forming	37.0
11. Siltstone; even-bedded with alternating, thin-bedded tabular sands; sandy layers up to 10 centimeters thick; siltstones reddish-brown; sandy lenses gray to buff, sometimes reddish-brown; calcareous with calcite and mudstone nodules; weathers to badlands	22.0
	218.0

Unconformity

PORPHYRITIC ANDESITE OF ?PAYANDÉ GROUP

Cerbatana Gravels and Clays

(Figs. 1 and 2, secs. F–J; map 2)

The strata between the top of the El Libano Sands and Clays and the base of the Monkey Unit are included in the Cerbatana Gravels and Clays. This unit is composed of massive, torrentially bedded conglomerates with current-bedded sandstone and siltstone lenses. The richly fossiliferous San Nicolás Clays exposed in the El Dinde and San Nicolás areas (map 2) are the largest of the silt and mudstone lenses and are part of the upper half of this unit. The basal part of the unit is composed predominantly of coarse sands and pebble conglomerates. Upward into the middle of the unit bedding becomes more torrential and the sandstones are replaced by pebble and granule conglomerates with scattered sandstone lenses. In the upper part, the beds become progressively more conglomeratic and torrential-bedding becomes extreme. Sandstones nevertheless persist (pl. 37, *a*). The mudstone and siltstone lenses vary greatly in thickness and lateral extent. Twenty-five or thirty lenses are present but only five are large enough to express on the geologic map. They occur sporadically through the section and show no definite evidence of gradational change. However, at the base of each of the five mapped lenses there is a basal concretionary sandstone.

The conglomerates (pl. 37, *a*, *b*) are light-brown to brick-red. The darker colors usually correlate with larger detrital materials and are most abundant near the top of the unit. Individual beds vary from less than 1 meter to more than 10 meters in thickness. Most of the conglomerates in the basal part of the unit are pebble gravels, the fragments becoming progressively larger toward the top of the section, until in the beds immediately below the Monkey Unit the conglomerates are composed of large-cobble gravels. These gravels and conglomerates form prominent cliffs throughout the area and produce the headlands of many of the drainage patterns in the region.

Sandstones in the Cerbatana unit are lenticular. Most of the lenses measure a few meters across (pl. 37, *a*), but a few can be traced for more than a kilometer. These larger masses show extensive cross-bedding of both diagonal and convex type, and are coarse- to fine-grained. Subangular to subrounded quartz makes up about 80 per cent of the mineral composition; feldspar, hornblende, micas, and metallic minerals are accessories. The sands are firmly packed but contain little or no calcareous cement. Near the base of the lenses, pebbles become more abundant and are usually oriented along the bedding planes. Finally, at the base, the sandstones grade into pebble gravels. Conversely, the upper parts of most of these strata contain thin silt and mudstone lenses and some have a concretionary upper surface (pl. 37, *c*; pl. 38 *a*, *b*).

The interbedded clays and siltstones of the Cerbatana Gravels are more or less alike in color and mineral content. Beds vary from 10 or 15 centimeters up to about 2 meters in thickness. Rounded quartz grains make up 70 or 80 per cent of the identifiable mineral fraction. Amphiboles and metallic minerals account for the remaining determinable percentages. These sediments are relatively well indurated but weather quickly to form extensive badlands. Thin sandy beds are usually present in the siltstones. Thickness and lateral extent of the five mapped clay lenses are quite variable (fig. 2, secs. F–J).

The richly fossiliferous San Nicolás Clays compose the thickest and most extensive lens within the Cerbatana unit. For the most part these clays are much like the other siltstone and mudstone lenses in the gravels. The lower part of the clays is sandy and rests upon a sandstone displaying large rounded concretions (pl. 37, *c*). The upper levels are progressively more silty and grade into clay near the top. The upper limit is marked by a massive, cross-bedded buff sandstone. Silt and clay beds in the San Nicolás Clays average about 25 centimeters in thickness.

SECTION OF CERBATANA GRAVELS AND CLAYS

(Thicknesses are averages)

MONKEY UNIT

CERBATANA GRAVELS AND CLAYS

	Meters
1. Concretionary sandstone; massive bedded, containing pebbles; dark-gray to speckled-gray on fresh surfaces, weathered surfaces with black desert varnish	2.0
2. Cobble and pebble conglomerate interbedded with massive cross-bedded sandstones and thin silty lenses; conglomerates red to brown, torrentially bedded; detritus 75 per cent chert, 25 per cent igneous; sandstones show northerly inclined current-bedding, coarse-grained, buff to dark-gray; cliff forming	15.0
3. Siltstone; sandy at base, grades into silts and buds at top; gray to reddish-brown; includes several massive sandstone lenses; calcareous nodules abundant	6.0
4. Cobble and gravel conglomerates with interbedded concretionary sandstone and several thin gray to brown silt lenses; conglomerates red, torrentially bedded; sandstones dark-gray, current-bedded, with torpedo-shaped concretions trending N 65° W; cliff forming.	21.0
5. *San Nicolás Clays:* sandy at base, grade upward into silt and mudstones separated by several irregular tongues of sandstone; silts gray to red; sandstone at base with large, coalescent, round concretions; richly fossiliferous	24.0
6. Conglomeratic sandstone with interbedded thin calcareous clay and siltstone tongues; sandstones show large scale diagonal and convex inclined current-bedding with oriented pellets and pebbles on bedding planes; sands light-gray in color, quartzose; bench forming	33.0
7. Siltstone; sandy at base, greenish-gray to reddish-gray; separated into upper and lower part by thin concretionary sandstone; upper part silty, calcareous, gray, green, brown, and rust	8.0
8. Concretionary conglomeratic sandstone; highly cross-bedded; upper part quartzose sand, no pebble or gravel lenses or pockets; lower part with oriented pebbles along bedding planes; grades into pebble conglomerate at base; cliff and bench forming	37.0
9. Claystone and siltstone; thin bedded greenish-gray to red, soft, calcareous, weathered surface littered with irregular calcareous siltstone concretions and calcite nodules.	8.5
10. Conglomerate with interbedded coarse sandstone and small, thin, silt lenses; conglomerates thick, torrentially bedded, brown to buff, detrital fragments of andesite, decite, granodiorite, chert, quartz and clay balls; sandstones cross-bedded with oriented pebbles along bedding planes, gray to buff, calcareous in places; siltstones thin, locally shaly, lenticular, brown to gray	84.0
	238.5

EL LIBANO SANDS AND CLAYS

All strata in the Cerbatana Gravels and Clays show considerable variation in thickness along strike (fig. 2). The San Nicolás Clays thicken greatly in the northwest part of the mapped area but disappear some distance to the north (fig. 2, secs. G–J). To the south the clays are partly cut off by a small hinge fault. South of the fault a thin greenish-gray to red clay lens is exposed which would be stratigraphically equivalent to the lower part of the San Nicolás Clays if the section were

normal, but field evidence indicates that it must be stratigraphically between the San Nicolás Clays and the siltstone (no. 7) on the foregoing section.

The variation in thickness of these beds is due in part to variations in the amount of sediment deposited but is also due to lithotope changes such as would be expected in channel and flood plain deposits. Both the upper and lower contacts of the lithologic units are gradational, and the contacts probably do not have the same time significance everywhere.

Monkey Unit

(Figs. 1 and 2, secs. A–E; map 2)

The richly fossiliferous Monkey Unit overlies the Cerbatana Gravels and crops out along the southern and southwestern dip slopes of the high escarpment formed in the Cerbatana Gravels. Here, as in the Cerbatana Gravels and Clays and El Libano Sands and Clays, the sandstones and claystones grade laterally into one another and are lenticular. Probably the most striking feature of this unit is the presence of large, elongate, torpedo-shaped concretions that stand in relief above the weathered surfaces of the sandstones. In any one bed these concretions, some of which are 15 meters long and 1 meter high, are oriented parallel to one another (pl. 38, *c;* pl. 39, *a*).

Richly fossilferous silts and claystones predominate over sands in the lower beds but give way to sandstones and pebble sands toward the top, although clays and silts are present throughout the section. Each sequence appears to represent minor cyclic deposition. Usually each cycle begins with deposition of coarse, cross-bedded sandstone, the upper part of which is calcareous and contains the torpedo-shaped concretions. Above this bed are more sands, usually without calcareous cement. These grade into sandy silt that weathers into blocks, followed by beds of soft silt, silty clay, and claystone. In the upper beds the laminae become progressively thinner and the upper 20 or 30 centimeters are shaly. These beds may change laterally from silt to clay to fine sand.

Composition of the silts and clays of the Monkey Unit is rather homogeneous. Rounded quartz grains make up about two-thirds to three-quarters of the determinable fraction. Hornblende and mica are common ferromagnesian constituents. Feldspar fragments and metallic minerals are rare. Calcareous cement may or may not be present but small calcareous concretions, rounded or irregularly shaped, are extremely abundant.

The Monkey Unit sandstones are usually characterized by diagonal and convex inclined current-bedding but horizontal bedding is also common. There are local pockets of coarse sand and pebbles but usually the sands are medium to fine grained, individual grains ranging from angular to rounded. Quartz makes up at least 80 per cent of the detrital fraction, and feldspar fragments average about 6 per cent. Hornblendes, mica, and metallic minerals constitute perhaps 8 to 10 per cent of the determinable fraction, giving a dark-gray, pepper-speckled appearance to the sands (tables 1 and 2). The lateral extent of the sandstones varies: some can be traced through most of the exposed area, others are traceable for only a few meters. The thickness of individual lenses is extremely variable, especially in those of wide lateral extent.[1]

[1] Separate listing of unit section measurements from the Monkey Unit through the Upper Red Bed is not considered necessary as individual beds and lenses are too small to warrant separation in field mapping. As an alternative the upper units of the La Venta section will be listed together.

Unit below Fish Bed

(Figs. 1 and 2, secs. A–E; map 2)

This unit crops out along the east slopes of the mesa north of Quebrada La Venta eastward through the area called Los Mangos and continues eastward across the divide between the La Venta and Tatacoa drainage basins. It is a succession of rather thin current-bedded sandstones interbedded with thin lentils and tongues of siltstone. This unit has only a few of the torpedo-shaped concretions that are so common in the Monkey Unit. It differs further in that the beds form a homogeneous sequence of alternating thin sandstones and siltstones.

The sandstones contain a high percentage of silt. Rounded quartz grains make up 90 per cent of the granular fraction; mica and magnetite are present in minute quantities (tables 1 and 2). Weathering is blocky, individual beds forming flat benches. Weathered outcrops are littered with pebble-sized concretions. Locally the silts and clays are sandy. In mineral composition they differ little from the sandstones (tables 1 and 2). The beds are soft and contain only slight amounts of calcareous cement. Weathered surfaces, however, are practically covered with small concretions.

Fish Bed

(Figs. 1 and 2, secs. A–E; map 2)

The Fish Bed is an easily recognized unit useful in correlation and mapping. It is thin, but continuous in lateral extent, and contains abundant fish vertebrae and pectoral spines, rodent teeth, coprolites, and other fragmentary fossil remains. It is distinct from any of the lower units, being an extremely fine-grained, clayey marl. The only determinable mineral grains are of well-rounded quartz (tables 1 and 2). The bluish-green color of the middle of the bed grades downward and upward into dull gray. The greatest thickness of the bed is 6 meters (fig. 2, sec. C); in places it thins to 2 meters.

Unit above Fish Bed

(Figs. 1 and 2, secs. A–E; map 2)

The color of this unit is very much like that of the unit below the Fish Bed but the proportion of clay and siltstone to sandstone is great enough to warrant calling the unit a siltstone with interbedded sandstone tongues and lentils. The upper part contains numerous thin cross-bedded sandstones. The siltstones and clays contain variable amounts of sandy material. Both the silts and sands weather into blocky chunks before complete disentegration. Eroded surfaces are covered with calcareous concretions. Successive beds vary in thickness from about 15 centimeters to over 1 meter.

Ferruginous Sands

(Figs. 1 and 2, secs. A–E; map 2)

The Ferruginous Sands form the most prominent ledges in the upper part of the La Venta section. The underlying units are much less resistant to erosion and weather into broad slopes and badlands. The upper surface forms a broad bench.

This unit is composed of sandstone with lenses of grit and conglomerate. The sands are coarse-grained, angular to subrounded, highly cross-bedded, and arkosic in composition. Quartz makes up about 47 per cent of the detrital material and

feldspar about 30 per cent. Hornblende, mica, and metallic mineral fragments are relatively abundant (tables 1 and 2), and the sands are loosely cemented with limonite. However, the resultant rust color is usually obscured by a coating of black desert varnish. The rust color is best seen near Los Mangos. To the east the color changes to deep rust-red and the beds are composed of fine- to medium-grained sand. To the west, the sandstone is predominantly gray and buff, the sands become very coarse, and there are numerous lenses and tongues of grit and pebble conglomerate. Torpedo-shaped concretions are again abundant and show the same parallel orientation as those in the Monkey Unit sands. In places these dark masses are so thick that they form comparatively smooth, resistant surfaces which protect the underlying sediments and allow formation of the main ledges. At the top of the Ferruginous Sands there is usually a half meter of thin-bedded, fissile, medium- to fine-grained yellowish-brown sandstone that grades into the overlying unit.

Unit between Ferruginous Sands and Lower Red Bed

(Figs. 1 and 2, secs. A–D; map 2)

This sequence of sandstones and clays crops out as a broad, irregular blanket over the dip-slope surface of the Ferruginous Sands. This unit is much like the unit below the Fish Bed. It is an accumulation of massive, cross-bedded to thin-bedded sandstones that alternate with lenses of silt and claystone. The thickest sandstone is 1½ meters thick and crops out at the top of the unit. It varies in thickness and in places is replaced by siltstone. The sandstones are more numerous in the upper part of the unit. They are fine- to medium-grained, rounded to subangular, and usually gray. Small pockets of grit, small pebbles, and a few clay balls are embedded in these sandstones.

The siltstones and clays are laminar in the upper part of the unit; lower in the unit they form beds averaging about 30 to 40 centimeters thick. Included grains are subrounded to rounded, and are predominantly quartz with minor amounts of feldspar, hornblende, and mica.

Lower Red Bed

(Figs. 1 and 2, secs. A–D; map 2)

The Lower Red Bed forms one of the more striking features in the La Venta area. Badland topography is strongly developed where the bed is exposed and the bed is easily identified from nearly any vantage point. As the name implies, it is dominantly a red bed, but the brick-red color is present only in the middle layers. The base is gray calcareous silty mudstone that grades laterally into thin clayey sand and upward into the typical red mudstone. In the upper layers the red color grades back into greenish-gray. The uppermost 2 meters grade into sandy siltstone.

Determinable grains are mainly of silt size; most are well-rounded grains of quartz. Hornblende, mica, and metallic minerals are scarce (tables 1 and 2). The beds contain perhaps 25 per cent clay, and when wet have a fairly strong kaolin odor; they are not, however, bentonitic. Calcareous cement is present in the upper and lower gray layers but lacking in the red strata. The red color of the middle layers is derived from limonite stain resulting from oxidation of iron-bearing minerals.

Unit between Upper and Lower Red Beds

(Figs. 1 and 2, sec. B–D; map 2)

This unit crops out as wide, flat, semibadland exposures between the Lower Red Bed and the Upper Red Bed. Its resistant sandstone base caps the Lower Red Bed and forms a broad bench throughout the areas of exposure.

Above the basal sandstone lie sandstone lenses and tongues—some thick, some thin—interbedded with silt and claystone. The sandstones show little evidence of cross-bedding. Detrital grains are for the most part rounded to subrounded quartz. Subangular to angular fragments of hornblende and rather large plates of mica make up about 5 per cent of the remaining identifiable fraction. Individual lenses and tongues are of restricted lateral extent.

The interbedded clay and silt show few traces of stratification. At the base the silts contain a high percentage of sandy material but upward they become almost shaly.

At the top of this unit is a ledge-forming sandstone that contains small irregular lenses of gravel. The base is locally conglomeratic and contains numerous clay balls, some as much as 9 centimeters in diameter, that seem to have come from the underlying clay.

In the area south of Los Mangos this unit, with its resistant sands and broad benches that dip southward, has diverted drainage south and west into the Upper Red Bed and from there into the Quebrada Las Lajas (map 2).

Around the headwaters of the Quebrada La Venta and eastward to the headwaters of the Quebrada Tatacoa certain beds in this unit are tuffaceous and contain minute glass shards and pumice fragments.

Upper Red Bed

(Figs. 1 and 2, sec. B; map 2)

The Upper Red Bed is perhaps the most spectacular deposit in the La Venta region. The area of exposure is extensive and badland topography is extremely well developed. This unit is easily differentiated from others as it is composed of rather thin layers (20 to 30 centimeter thick) of even-bedded, dull-red claystone with numerous thin interbeds of gray claystone (pl. 40, *a*).

The basal and uppermost layers of the Upper Red Bed, like those of the Lower Red Bed, are not red. The most significant mineralogical feature displayed by the Upper Red Bed is the presence of bentonite, which constitutes some 35 per cent of the material composing the beds. Montmorillonite is evidently the constituent mineral, as the clay swells and slumps when placed in water. Quartz is present as extremely small rounded grains and constitutes about 60 per cent of the detrital fraction. Muscovite is also present (tables 1 and 2). The red limonite stain is not soluble in cold hydrochloric acid but is completely soluble in hot hydrochloric acid. After the stain is dissolved, the clay residue is the same greenish-gray color as the upper and lower beds of this unit, indicating that all but the middle layers were probably leached before or shortly after deposition.

The presence of bentonite is significant, for only in the unit below the Upper

Red Bed are there any traces of volcanic materials. This occurrence in the Upper Red Bed foreshadows the abundance of volcanic materials in the Las Mesitas beds and in the highly tuffaceous beds of the overlying Gigante group (pl. 39, *c*).

SECTION FROM UPPER RED BED THROUGH MONKEY UNIT
(Thicknesses are averages)

LAS MESITAS SANDS AND CLAYS

UPPER RED BED–MONKEY UNIT SECTION

	Meters
1. *Upper Red Bed:* bentonite clays, sandy and silty at base and upper layers; base gray, grading into dull red separated by thin greenish-gray laminae; upper beds greenish-gray; calcite nodules; forming extensive badlands; some vertebrate fossils	70.0
2. *Unit between Upper and Lower Red Bed:* gray sandstone lenses and tongues interbedded with gray to brown siltstones and mudstones; sand with scattered conglomerate lentils and beds; ledge forming; vertebrate fossils	45.0
3. *Lower Red Bed:* mudstone, middle beds brick-red grading above and below to greenish-gray; calcareous with numerous small concretions and nodules on weathered surfaces; forming extensive badlands	14.5
4. *Unit between Ferruginous Sands and Lower Red Bed:* massive, cross-bedded to thin-bedded sandstones interbedded with lenses of thinly laminar gray, greenish-gray, pale-red, rust, and brown siltstone; ledge forming; vertebrate fossils	35.5
5. *Ferruginous Sands:* arkosic, coarse-grained, angular to subrounded, highly cross-bedded sandstone; locally with conglomeratic lenses and tongues; torpedo-shaped concretions abundant; beds loosely cemented with limonite; rust to buff, color usually obscured by black desert varnish; ledge and bench forming	13.0
6. *Unit above Fish Bed:* thin, current-bedded gray sandstones interbedded with gray, greenish-gray to rust siltstones and clays; calcareous in places with small concretions and nodules; ledge forming; vertebrate fossils	10.0
7. *Fish Bed:* marker bed; bluish-green, thin, extremely fine-grained clayey marl with abundant coprolites, fish vertebrae and spines, and rodent teeth	3.0
8. *Unit below Fish Bed:* gray, brown, reddish-brown, greenish-gray siltstones and clays with numerous thin, gray, laterally restricted, cross-bedded sandstone lenses, calcareous nodules and concretions; vertebrate fossils	21.5
9. *Monkey Unit:* siltstone and claystone interbedded with sandstone lenses and tongues; silts and clays most abundant in lower beds, gray to reddish-brown with cyclic bedding; sandstones current-bedded with local pockets of coarse grit and pebbles, partly calcareous; characterized by large parallel torpedo-shaped concretions; vertebrate fossils.	35.5
	248.0

CERBATANA GRAVELS AND CLAYS

Las Mesitas Sands and Clays

(Fig. 2, sec. B)

This unit overlies the Upper Red Bed and crops out in the area south of the La Venta badlands along the road from Villavieja to Baraya. It is a thick sequence of gray sandstone alternating with reddish-brown to gray siltstones and clays (tables 3 and 4). Throughout this section there are lenses and tongues of pebble conglomerate and numerous tuffaceous and bentonitic beds (tables 3 and 4). Here, as in the La Venta section, the sands and clays grade laterally into one another. Individual strata are of minor lateral extent. Total thickness is not known.

TABLE 3

MECHANICAL ANALYSIS OF SEDIMENTS: COYAIMA, CARMEN DE APICALÁ, AND LAS MESITAS

Sample	Grain roundness	Cement	Millimeters						
			Above 1	1 to 1/2	1/2 to 1/4	1/4 to 1/8	1/8 to 1/16	1/16 to 1/256	Below 1/256
Coyaima	rounded	calcareous	8.0	25.0	30.0	18.0	11.0	8.0	....
Coyaima	rounded	calcareous	12.0	6.0	8.0	29.0	20.0	25.0	....
Carmen de Apicalá	rounded to subrounded	calcareous	....	2.0	12.0	35.0	32.0	19.0	....
Carmen de Apicalá	rounded	calcareous	37.0	17.0	2.0	15.0	20.0	9.0	....
Las Mesitas	rounded	none	....	....	....	3.0	15.0	22.0	60.0
Las Mesitas	rounded to subrounded	calcareous	....	23.0	55.0	12.0	6.0	4.0	....

TABLE 4

MINERAL ANALYSIS OF SEDIMENTS: COYAIMA, CARMEN DE APICALÁ, AND LAS MESITAS

Sample	Quartz (rock and crystal)	Feldspar (all)	Hornblende	Mica (Muscovite and Biotite)	Magnetite and Ilmenite	Rock fragments	Clay minerals	Indeterminate	Remarks
Coyaima	58.0	18.0	2.0	2.0	5.0	8.0	....	7.0	.....
Coyaima	79.0	4.0	0.5	1.5	3.0	6.0	....	6.0	.....
Carmen de Apicalá	80.0	5.0	3.0	2.0	2.0	2.0	....	6.0	.....
Carmen de Apicalá	50.0	5.0	....	1.0	2.0	35.0	trace	7.0	.....
Las Mesitas	68.0	....	....	2.0	trace	....	30.0	....	bentonitic
Las Mesitas	48.0	30.0	trace	trace	2.0	20.0	....	....	.....

Quaternary

Mesa Conglomerate

(Fig. 2, sec. D; map 2)

The Mesa Conglomerate rests unconformably above all the Tertiary sediments in the Cerro Gordo–Villavieja–Baraya region. In the La Venta badlands this Pleistocene conglomerate overlies various parts of the Honda group with distinct angular unconformity.

This cap rock consists of some 25 meters of reddish-brown, poorly sorted, well-rounded boulder conglomerate that grades in some places into cobble and pebble gravel that contains grit and coarse sandstone lenses. The cobbles and boulders are of granodiorite, quartz, chert, porphyritic andesite, microcrystalline andesite, and metamorphic rocks. The matrix is a mixture of fine-textured sandy clay and tuff.

Secondary Sedimentary Structures

The most interesting secondary structures in the La Venta badlands are the torpedo-shaped concretions. Other concretionary structures are present but none seem as difficult to explain.

These concretions are quite resistant and many of them weather into forms 15 meters long and 1 meter across. In any one stratum the long axes of the concretions are oriented parallel to one another (pl. 38, *c*). Within a single bed the concretions may range from about 1 meter to about 15 meters long. The simplest are elongated, with large blunt heads that taper to narrow tails. In any one bed, the blunt heads are all at the same end. In cross-section the usual shape of a concretion is that of an inverted U. Some appear to be composite bodies (pl. 38, *c*). The bases of individual concretions normally blend into the underlying sandstone so that no definite boundary can be seen. The bottoms of some, however, are fairly flat surfaces whose edges curve upward and are continuous with the sides of the concretions.

The material in the concretions is usually the same as in the underlying sandstone but some contain grit and very small pebbles. Calcite is the cementing mineral but limonite is usually present as well and probably aids in cementation. Their structure is normally concentric but is not well developed: many concretions were broken open, but a nucleus was not found in any of them. Efforts were also made to determine whether the bedding planes of the host rock pass through the concretions: here again the evidence was negative, for none showed bedding planes. In several levels silts occupy the areas around the concretions and there is a sharp break of texture between the two. However, where this was observed, the material directly below the concretions was of the same or nearly the same grain size and mineral composition as the concretions.

The origin of these concretions might be explained in the usual manner; i.e., after deposition of the containing sediments, the mineral substance of which they are made was collected from the surrounding rock by percolating waters and then redeposited (Pettijohn, 1949, p. 149). This explanation requires that there be a nucleus or axis about which accumulation of mineral matter might take place. I do not question the postdepositional formation of these concretions, but the lack of nuclei, and their large, elongate shapes, parallel orientation, and consistent trend

in any given stratum suggest a different origin. The following explanation is suggested.

Deposition of strata in the La Venta area appears to have been sporadic. Red strata throughout the section offer evidence of oxidization and thus of subaerial weathering. On the other hand, the many gray and greenish-gray beds indicate reduction. Within the Upper Red Bed gray laminae are variously spaced between the red beds. However, the basic mineral composition of both the red and gray materials is the same. Intermittent wetting and drying caused the oxidation and resultant redness—the gray beds are deposits which were not dried, and thus never oxidized. Red and gray strata could alternate as they do only if periods free, or almost free, from flooding had alternated with periods during which flooding and deposition were constant.

As noted earlier, calcium carbonate is the common cementing material in this depositional sequence. The carbonate, according to Butler (1942), may have originally been precipitated in a finely disseminated form throughout the sediments during their deposition by saturated superficial waters draining an area of Cretaceous limestone.

If the beds that now contain the torpedo-shaped concretions had been subjected to drying heat evaporation would have caused the disseminated calcareous material to precipitate for some depth below the surface. This crystallization and the resultant hardening of the sands would probably not have been uniform. Certain areas would have dried more quickly than others because of irregularities in surface profile.

When flooding began again, currents would probably cause erosion of these sands. Those areas in which cementation had progressed more rapidly would be more resistant to abrasion and might act as buttresses around which the currents would be deflected. The result would be a torpedo-shaped mass with a blunt head and a tapering tail pointing downstream. Even if the trailing portion were relatively uncemented compared to the upstream head it would be preserved by the deflecting effect of the head.

Later deposition, either of material lithologically similar to that in the hardened masses or differing from it, would bury the entire area of oriented masses. After burial, the previously cemented masses would act as parallel axes about which additional crystallization would probably take place.

If the foregoing explanation is accepted it may be concluded that the number of strata containing concretionary masses indicates the number of periods of subaerial exposure during the time represented by the units in which they occur. The alignment of these structures indicates the current direction of the transporting streams and thus provides a possible clue to the source area for the sediments of the Honda group in the La Venta area. The trend of the concretions varies from about N65°W to N45°E, but if an average of all readings is taken, the concretions indicate a general stream flow from south to north.

STRUCTURE

The sediments of the La Venta–Cerro Gordo region dip gently away from Cerro Gordo. The regional strike and dip are strongly modified in the faulted zone west of Cerro Gordo, south of the hinge fault in the El Dinde area, and by a low south-

west-plunging anticlinal nose in the El Libano area. There is also a synclinal nose west of San Nicolás. The La Venta–Cerro Gordo region lies on the east flank of the so-called Magdalena graben, a north-south structural feature of regional deformation associated with the rejuvenation of the Cordillera Central and uplift of the Cordillera Oriental. The development of this graben, according to J. L. Anderson (1945), began at the close of Cretaceous time and was completed during the significant orogeny of the Pliocene. Butler (1942) doubts the graben theory of the origin of the Magdalena Valley.

The Honda beds within the area mapped appear to have been raised into a low dome with Cerro Gordo as apex. On the west side of Cerro Gordo the beds strike N20°E and dip 8°W. Along the southwest flank the strike swings westward; along the section line 0–0′ (see map 2) the beds strike N42°W and dip 10°SW. To the south flank of Cerro Gordo the strike is N69°E and the dip is 8°S. From Cerro Gordo outward to El Libano the dip gradually decreases from 8° to about 5°.

Folds

EL LIBANO ANTICLINAL NOSE

Quebrada Libano appears to follow the axis of a small anticlinal nose in the Honda beds. The axis of this fold plunges southwest from Cerro Gordo, flattening and disappearing a short distance southwest of El Libano. Along the southeastern flank of the nose, the beds strike N74°E and the average dip is 8°S. The northwest flank of this structure has an average dip of 8°W and strikes N–S. The strike of the beds along the axis is N44°E. Near the contact of the Honda beds with the ?Payandé group the dip is 10°SW. Outward along the plunging axis the dip gradually decreases to about 4°SW.

The outcrops over much of the anticlinal nose are in the El Libano Sands and Clays, but to the southwest the lower limits of the Cerbatana Gravels and Clays are also involved in the fold.

SAN NICOLÁS SYNCLINAL NOSE

The area west of San Nicolás lies at the end of a westward-plunging synclinal trough whose axis trends almost due west. The syncline, which extends an unknown distance west of the railroad right-of-way, is paralleled to the south by a small hinge fault whose displacement is slight. The beds on the north edge of the nose strike N53°W and dip 2°SW. At the south edge of the nose and north of the hinge fault, strike is N27°E and dip is 5°W.

The oldest beds exposed along the axis of this synclinal nose are the San Nicolás Clays. Part of the upper strata of the Cerbatana Gravels and Clays caps the San Nicolás Clays along the trough of the syncline.

OTHER MINOR FOLDS

South of the hinge fault near El Dinde is a small synclinal flexure whose axis trends east–west. This trough parallels the hinge fault and is of small extent.

Faults

Faults are an unimportant feature of the geologic structure of the Cerro Gordo–La Venta area; the longest fault is less than 2 kilometers long, and maximum displacement is probably less than 30 meters. All are shown on map 2.

The faults on the north limb of the El Libano anticlinal nose are probably a series of small, echelon, dip-slip strike faults. The beds immediately west, on the hanging wall, dip from 27° to 57°W apparently from drag along the faults. The normal dip in this area is only 4° to 8°W. The displaced zone extending northward from the school house at El Libano is interrupted by a short strike-slip dip fault that is probably intraformational, as it can not be traced into the units above or below.

The hinge fault in the El Dinde area is of extreme importance in the geologic history of the area. This fault is a normal hinge fault whose terminus point lies some 140 meters east of the jeep road to San Nicolás and 245 meters S40°E from Casa El Dinde. Rocks north of this east-west fault have been displaced downward in relation to those on the south side. This fault extends westward for an unknown distance and its maximum observed displacement is 10 meters.

The San Nicolás Clays abut against the escarpment of this fault and show normal bedding. There is no indication of drag due to displacement. Toward the west, where erosion has not removed the upper beds of the San Nicolás unit, the clays overlap the escarpment and are exposed on the south side of the fault (see pl. 39, *b* and map 2). It appears that this fault predated deposition of the San Nicolás Clays and that they were deposited in the depression developed by the displacement.

GEOLOGIC HISTORY

During the Mesozoic era the La Venta region was part of the North Andean geosyncline, which centered along the axis of the present Cordillera Central. West of the present Magdalena River there was a mobile zone which in part coincided with the present Cordillera Central. The North Andean trough had its beginning in the early Mesozoic, at which time the Jura-Triassic ?Payandé limestones, clastic sediments, and andesites were laid down. At the close of Jurassic time, crustal disturbance, revealed by local unconformities (Trumpy, 1943; Anderson, 1945) and by the transgressive nature of the Cretaceous seas with thick marginal conglomerates containing pebbles of earlier Mesozoic rocks, prepared the way for the vast marine deposits of the Cretaceous period (Hedberg, 1942). In the Cerro Gordo–La Venta area no Cretaceous rocks are exposed. However, east of Cerro Gordo, along the Rio Cabrera and again in the vicinity of Baraya, beds assigned to the Cretaceous are present (Royo, 1942*c*). These rocks overlap the ?Payandé group with angular unconformity.

The Mesozoic was brought to a close in the North Andean basin by broad epeirogenic movements. The sea withdrew slowly from the south toward the north, but deposition continued into the Eocene in deeper parts of the geosyncline. The sea's withdrawal was marked by a lithologic change in the character of the sediments. It was not until the Eocene that pronounced orogeny took place, separating the North Andean geosyncline into several intermontane troughs, the geosyncline itself passing out of existence (Anderson, 1945). This epoch was accompanied by intrusions of dioritic and granitic rocks along the axis of what is now the Cordillera Central (Grosse, in J. L. Anderson, 1945). Evidence indicates, however, that during Eocene time the mountains were not high and uplift took place only in local areas. Butler (1942) suggests that the Cordillera Oriental, to the east, may not have existed at that time.

Sediments assigned to the Eocene and Oligocene epochs do not occur in the La Venta area, but to the east, near Baraya and elsewhere in the Upper Magdalena Valley, such sediments are known. According to Anderson (1945) and other writers, the Eocene sediments came from the southeast and south. Following deposition of this Eocene sequence the area of the present Upper Magdalena Valley was subjected to folding, faulting, and subsequent erosion. Deposited over the irregular surface of the eroded Eocene rocks was a sequence of coarse clastic sediments assigned to the Oligocene epoch by Butler (1942). Stirton (1947*b*), on evidence from fossil vertebrates, established an early Oligocene age for beds assigned to this sequence near the village of Chaparral, and (1953*b*) applied the name Gualanday group to these rocks.

None of these early Tertiary deposits occur between Cerro Gordo and La Venta but from evidence available in surrounding areas it is apparent that early Tertiary sediments underlie the Honda group. Usually there is no evidence of angular unconformity between the Honda group and the underlying sediments but local disconformities have been reported.

Deposition of Honda-type sediments apparently did not begin at the same time in all parts of the Magdalena basin. At Coyaima, coarse clastic sediments belonging to the Gualanday group are disconformably overlain by pebble sand, coarse sand, and silt considered to be part of the Honda group. These beds are fossiliferous and have been assigned to the upper Oligocene (Stirton, 1953*b*). At Carmen de Apicalá in the Melgar basin 20 kilometers southwest of Girardot, Tolima, is a sequence of beds also referred to the Honda group. These rocks overlie beds probably belonging to the Gualanday group. Fossil rodents found at Carmen de Apicalá correlate with the rodent remains from the La Venta badlands and are late Miocene in age (Fields, 1957).

As stated in the discussion of the Honda group, Butler (1942) was able to distinguish an upper and lower part of the sequence. Mineral and mechanical analysis of samples from Coyaima (tables 3 and 4) seem to support Butler's conclusions. The Honda beds at Coyaima rest disconformably over the Gualanday group and the fossils indicate that this part of the Honda was laid down in late Oligocene time. The age designation, based on fossil mammals (Stirton, 1953*b*), plus the lithologic character of the Coyaima beds places them in Butler's lower Honda.

The beds at Carmen de Apicalá do not show definite relationship with either the upper or lower Honda as characterized by Butler (tables 3 and 4). However, fossil rodents from that locality indicate that these beds were laid down in late Miocene time. The deposits rest directly upon sediments tentatively assigned to the Gualanday group by Stirton (1953*b*).

The dating of the Honda beds in the La Venta badlands as late Miocene is based on age designation of contained fossil mammals. This evidence, correlated with the lithologic character of the beds (tables 1 and 2), places the La Venta beds in Butler's upper Honda. It is unfortunate that fossil mammals have not been found in the type area of the Honda. If such were known, a great deal more could be said concerning the time of deposition of the entire Honda group. Royo (1942*c*) reports the presence of lower Honda sediments in the vicinity of Potosi and between Villavieja and Baraya. These were not seen by me and are definitely not exposed in the La Venta badlands. It is probable that lower Honda sediments are present

in this area, but folding is so slight that if they are they have not been exposed by erosion.

From field evidence obtained in the surrounding region it can be assumed that the elevation of the mountain regions which began in the Eocene was responsible for deposition of the coarse conglomerates and interbedded shales of the Oligocene Gualanday group. Differential uplift produced minor local disconformities between the Gualanday and Honda groups. Honda deposition did not begin at the same time in all areas of the upper Magdalena Valley, probably because of differences in surface profile in the primordial Magdalena Valley and development of partly or wholly isolated basins of deposition along the flanks of the main drainage basin.

The La Venta sediments, as well as other parts of the Honda group, were laid down over the alluvial and floodplain deposits of the Gualanday group and older, partly peneplaned sediments; they may have extended, as Butler (1942) suggests, over parts of the present Cordillera Oriental. It is apparent that the physiographic conditions of earlier Tertiary time continued during the Miocene. The site of deposition of the Honda beds must have been a broad, relatively flat floodplain through which the ancestral Magdalena River and other rivers probably flowed.

From the mineral suite present in these beds it appears probable that the chief source areas of sediments were to the south and west. Much of the hornblende was probably derived from disintegration of granitic and dioritic plutonic rocks in the Cordillera Central. It thus appears that during the time represented by Honda deposits, erosion exposed the batholiths underlying the Cordillera Central. This mineral suite is rare or lacking in sediments older than the Honda group (Butler, 1942). The presence of andesitic pebbles in the La Venta section agrees with Butler's finding in the upper Honda section at Honda. Igneous rocks of this type are common south and southwest of the upper Magdalena Valley and the andesitic pebbles seen in the La Venta section probably came from those areas.

During deposition of the El Libano Sands and Clays, the source areas were relatively low, but had a heavy seasonal rainfall. During wet seasons, flooding streams spread fine-grained silt and clay over vast areas of the pre-El Libano floodplain. At the same time streams meandered across the lowland, depositing sand and small amounts of pebble gravel in their circuitous channels. The streams also deposited calcium carbonate, which probably had been taken into solution as they passed over Cretaceous limestones. Oxidized zones indicate periods of wetting and drying, probably a result of cessation of flooding during dry seasons when streams partially withdrew from the flood plains.

Cerro Gordo evidently stood above this late Miocene floodplain much as it stands above the La Venta badlands today. Within the clays surrounding Cerro Gordo are numerous angular blocks of andesite, evidently washed onto the floodplain and buried by the El Libano Clays.

Greatly increased rainfall, orogeny, or both are indicated by the conglomeratic character of the Cerbatana Gravels and Clays. Outcrops of Cretaceous chert as well as areas containing metamorphic and igneous rocks contributed coarse clastic material. The source of the cherts is problematical, as Cretaceous cherts are found on the flanks of both the Cordillera Central and Cordillera Oriental. Abundant dacite and andesite pebbles reflect volcanism that accompanied or immediately

followed the slight disturbance that ushered in the time of deposition of the upper Honda (Butler, 1942).

The basal parts of the Cerbatana Gravels and Clays give only a slight indication of later events. The contact between this unit and the El Libano Sands and Clays is marked by a change from predominance of silt and clay to predominance of coarse sand. As time went on there must have been an increase in rainfall accompanied by increased stream gradient. Flooding was extensive and probably continuous. Out on the floodplain, sand was deposited at a rapid rate; in quiet, protected pools, silts and clays accumulated. Along stream courses, great quantities of coarse sand and moderate amounts of gravel were dumped. Steep diagonal and convex inclined bedding in the sands and torrential-bedding in the conglomerates are proof of extensive floods. Before deposition of the San Nicolás Clays there was evidently a period of less rainfall, for sand predominates over gravel in the beds immediately below the San Nicolás Clays. However, orogeny was still taking place, not only in the source areas, but in the La Venta area itself. Field evidence indicates that it was at this time that the Cerbatana gravels were displaced by the hinge fault seen in the El Dinde area. The depression formed by this fault must have created a small lake or lagoon in which the San Nicolás Clays were deposited. In time, sediments completely filled the depression and buried the scarp of the fault. Clay then spread over some of the surrounding terrain. In other parts of the region, clays were deposited in flooded areas and current-bedded sands filled stream channels. As sedimentation proceeded, flooding again became extreme. Tremendous amounts of torrentially-bedded coarse sand and conglomerate spread over the floodplain. Gradually the floods abated, and by the end of Cerbatana deposition only coarse sand was being transported by the streams.

By the time post-Cerbatana deposition began, climate and relief were again as they were during deposition of the El Libano Sands and Clays. Streams spread sandy silt and mud over wide areas of the Cerbatana gravels, and current-bedded sands were deposited along stream channels. Seasonal wetting and drying is suggested by oxidized strata in the clays and by development of torpedo-shaped concretions in the sands. Before deposition of the marl of the Fish Bed, the streams must have become choked with sediments. The wide lateral extent, thinness, and marly character of the deposits and the abundance of fossils indicate that the Fish Bed was deposited in a lake.

Increased rainfall, perhaps accompanied by rejuvenation of stream gradients, brought an end to the Fish Bed lake. The heavily laden streams poured their burdens into the lake, until its basin was filled with silt; then, once again, streams meandered across the floodplain, depositing silt and sand.

Further increase of rainfall in the source areas brought about what appears to be sheet-flood deposition of the Ferruginous Sands. The thin but even lateral distribution of this unit together with increasing coarseness toward the west and smaller grain size to the east may indicate that the sediments were derived from the west.

Following accumulation of this sheet-flood material more sand and clay was deposited. Streams again became choked, and a playa-like lake was formed; in it the sediments of the Lower Red Bed were deposited, their red color presumably resulting from subaerial oxidation of iron-bearing minerals they contained.

Extensive flooding followed deposition of the Lower Red Bed. Clays again spread over the lowlands and sands came to rest along river channels. At this time there was renewed volcanism in the Cordillera Central, as shown by small deposits of volcanic ash in the beds above the Lower Red Bed.

Conditions which caused formation of the Lower Red Bed were evidently repeated on a much larger scale during deposition of the Upper Red Bed except that this bed is composed of altered volcanic ash swept into the area by streams and possibly by winds from the Cordillera Central.

Continual flooding is again indicated at the top of the Upper Red Bed. The absence of red coloring indicates subaqueous reduction. Upper Red Bed deposition ended when the area once again became a floodplain. The Las Mesitas deposits with their thick beds of sandstone were laid down along stream channels and silts containing bentonite were spread over the floodplain. These deposits record the inception of a period of intense volcanism.

Butler (1942), Anderson (1945), and other writers report that a period of diastrophism ended Honda deposition and caused a disconformity between the Honda and the overlying pyroclastic "Gigante" formation (Richmond Petroleum Company terminology). Butler (1942) reports intensive folding and faulting of the Honda group in the area around Honda. It was probably at this time that the structural features in the La Venta badlands were developed (except for the earlier hinge fault in the El Dinde area).

The Jura-Triassic complex of Cerro Gordo was rejuvenated, creating a dome-like structure. The Honda beds were tilted around the flank of the dome and differential stresses caused faulting at El Libano.

It was during this period that the broad major features of regional structure were developed and the Magdalena Valley trough outlined structurally for the first time (Butler, 1942). These features are most probably post-Miocene in age, as the fossil evidence for dating upper Honda deposition is late Miocene. Doubtless, erosion accompanied this period of deformation and it was perhaps then that the primordial Magdalena River took on its present drainage pattern.

Over the eroded surface of the post-Honda Magdalena Valley, great thicknesses of Gigante tuffs, fluvial sands, silts, and clays were deposited. The distinct pyroclastic aspect of these sediments differentiates them from all known older formations of the region. Distinct bedding is characteristic throughout and it appears that the pyroclastic deposits were for the most part fluvial in origin, although winds may have transported considerable amounts of ash into the area to be mixed with the fluvial sediments. The abundance of pyroclastic sediments demonstrates that volcanoes in the Central Cordillera were important sources of material. It is not known whether these pyroclastic sediments were laid down over the La Venta area. If they were, erosion removed them long before deposition of the Pleistocene Mesa Conglomerate.

The exact age of the Gigante tuffs is not known, although they are post-Honda and older than the Mesa Conglomerate. No fossil mammals have been found in these beds. Fragments of fossil wood and leaves are present but they are so poorly preserved that they are of no value in dating. From their stratigraphic position and from diastrophic data, I feel fairly certain that the tuffs are Pliocene—but how much of the Pliocene is represented is not yet determinable.

Later, probably at the close of the Pliocene and the beginning of the Pleistocene, vigorous erosion dissected the thick alluvial deposits of the Gigante floodplain and left the present isolated and irregular mesas of the Gigante formation along the Neiva-Villavieja road. Another period of rejuvenation in early Pleistocene time brought about deposition of the Mesa Conglomerate on a wide piedmont plain that extended from the surrounding mountains, especially those to the west, by coalescence of alluvial fans.

Mid-Pleistocene to sub-Recent erosion dissected these coarse sediments and created the present valley floor in which the Magdalena River is entrenched. In the La Venta area remnants of the Mesa Conglomerate lie unconformably over parts of the Honda group and are undergoing further erosion. In places a desert pavement of cobbles and boulders derived from the Mesa Conglomerate is scattered over the badlands.

During late Pleistocene time, alluvium was deposited along stream courses. Today, the Magdalena River and its tributary streams are incising themselves into rocks of the Honda group and older sediments, and are depositing younger silts, sands, and gravels in favorable sites along their courses.

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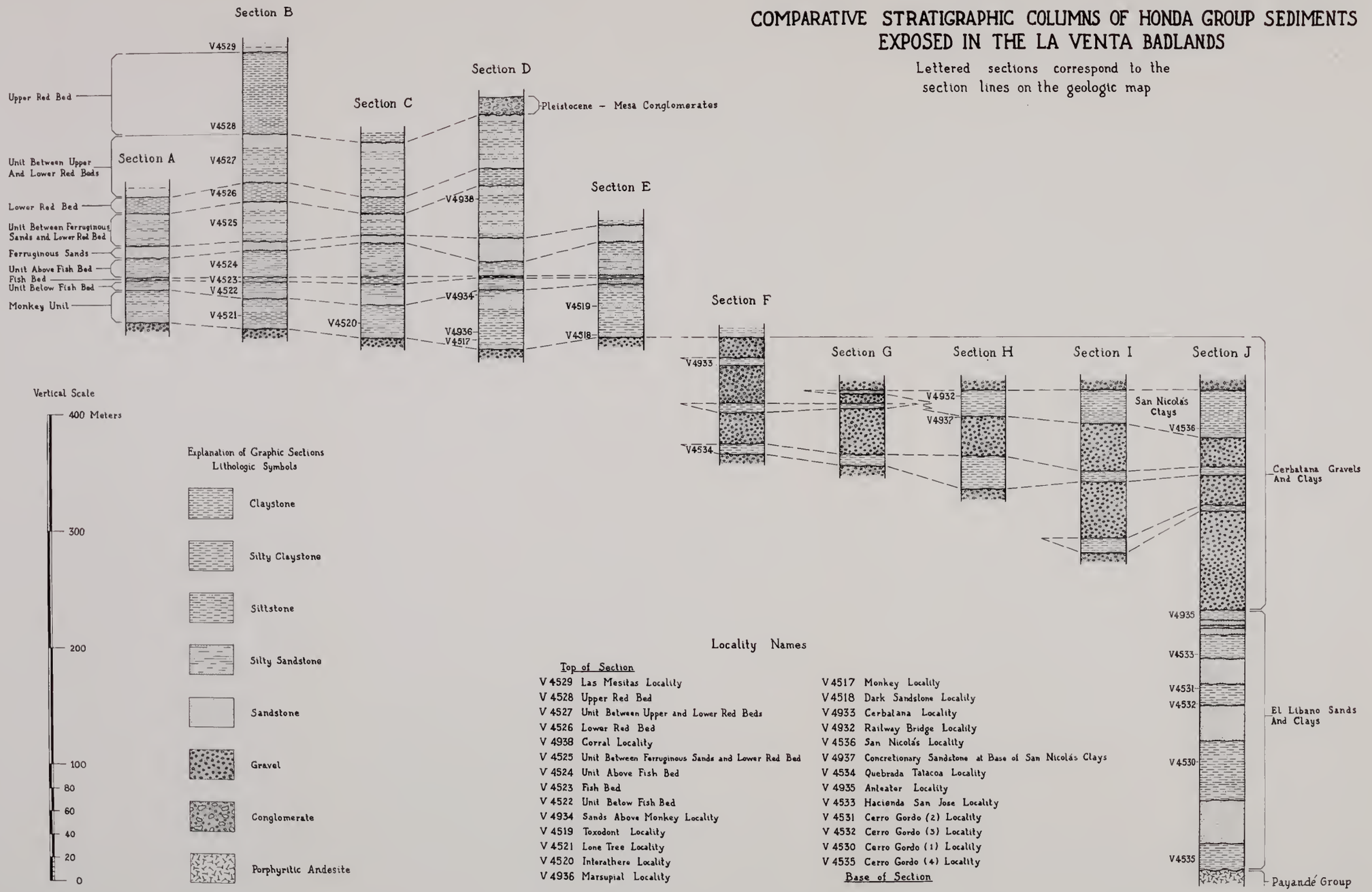
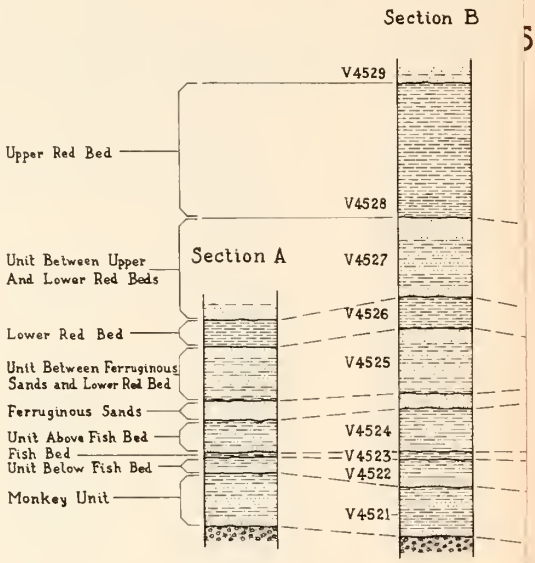
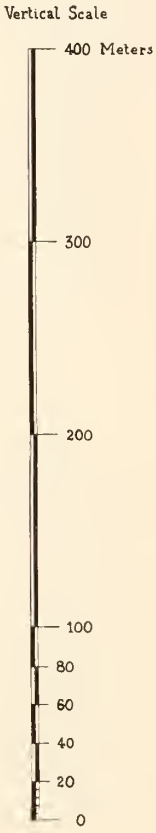
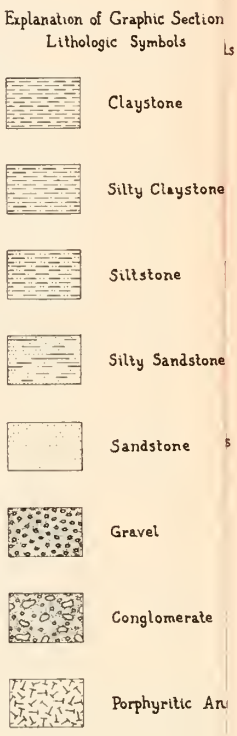


To accompany Robert W. Fields, "Geology of the La Venta Badlands, Colombia, South America," Univ. Calif. Publ. Geol. Sci., Vol. 32, No. 6.

Figure 2. Comparative stratigraphic columns of Honda group sediments exposed in the La Venta badlands. Letter sections correspond to the section lines on the geologic map.







To accompany Robert W. Fields, "Geology of the La Venta Badlands, Colombia, South America," Univ. Calif. Publ. Geol. Sci., Vol. 32, No. 6.

DETAILED GEOLOGIC MAP
OF THE AREA FROM
CERRO GORDO TO LA VENTA
HUILA, COLOMBIA, SOUTH AMERICA

By
Robert W. Fields and Diego Henao-Landoño
Prepared in cooperation with the Servicio
Geológico Nacional de Colombia
1949

0 100 500 1000 2000 METERS
0 2 KILOMETERS

Contour interval – 10 meters
Datum is mean sea level

Strike and dip

High angle fault
(U-upthrown side D-downthrown side)

Dip-slip strike fault
(D-downthrown side)

O-O'-O"-Line of Cross Section shown in Fig 2
A-A-Line of Traverse for Measured Stratigraphic columns

Pleistocene
- Mesa Conglomerates

Miocene — Honda group
- Upper Red Bed
- Unit Between Upper and Lower Red Beds
- Lower Red Bed
- Unit Between Ferruginous Sands and Lower Red Bed
- Ferruginous Sand
- Unit Above Fish Bed
- Fish Bed
- Unit Below Fish Bed
- Mankey Unit
- Cerbotono Grovels and Cloys including San Nicolás Cloys
- El Líbano Sands and Cloys

Juro-Triassic
- ?Poyondé group – Purple Limestone and Porphyritic Andesite Intrusives

El Líbano
Quebrada El Líbano
Quebrada Tatacoa
San Nicolás
El Dinde
Quebrada La Venta
La Venta
Los Mangos
Camino de Heradura
a Villavieja
a San Alfonso
Carretera para Jagp
Carretera
Jagp
Neiva-Girardot
Ferrocarril
O Cerbatana
CERRO GORDO

To accompany Robert W. Fields, "Geology of the La Venta Badlands, Colombia, South America," Univ. Calif. Publ. Geol. Sci., Vol. 32, No. 6.

Map 2. Geologic map of the La Venta badlands.

PLATES

PLATE 37

a. Cerbatana Gravels. Bluff of pebble and cobble conglomerate showing cross-bedding, sandstone lenses, and disconformity with underlying silt. Ledge about 4 meters high.

b. Cerbatana Gravels showing oriented pebbles and cobbles. Exposures along Quebrada Cerbatana.

c. Concretions at base of San Nicolás Clays. Concretions average 50 centimeters in diameter.

a

b

c

PLATE 38

a. Concretionary sandstone at base of Monkey Unit. Concretions are smaller and more scattered than those at the base of the San Nicolás Clays.

b. Concretionary sandstone at base of Monkey Unit. Near view showing porous surface of coalescent bun-shaped masses.

c. Torpedo-shaped concretions standing in relief from sandstone in the upper part of Monkey Unit. Note parallel alignment of masses.

a

b

c

PLATE 39

a. Torpedo-shaped concretions in Monkey Unit showing parallel orientation. Large concretion in left foreground about 15 meters long.

b. Hinge fault in Cerbatana Gravels with San Nicolás Clays overlapping edge of escarpment. Hinge terminus of fault at upper left, behind tree.

c. Erosion remnants of Gigante formation tuffs exposed along Neiva-Villavieja road.

a

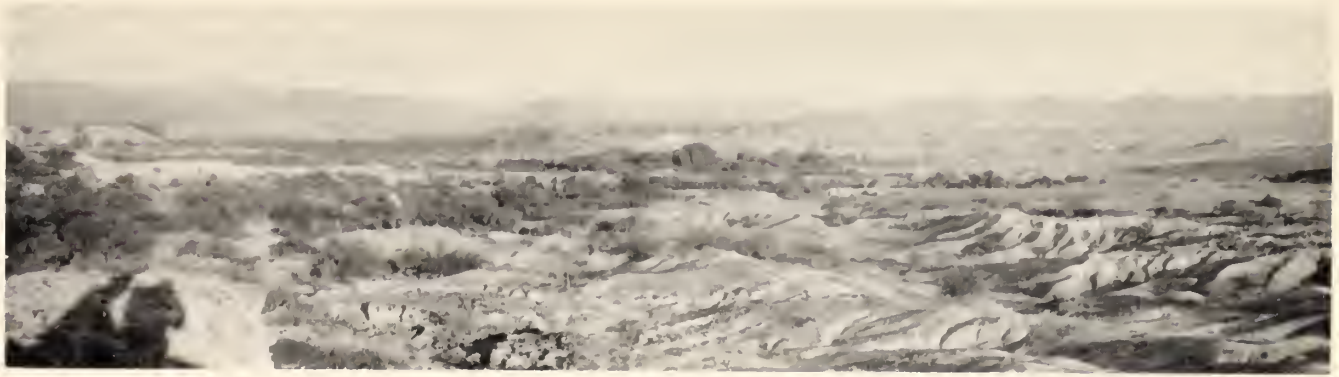
b

c

PLATE 40

a. Upper Red Bed. Exposures in the La Venta badlands showing persistence of color laminae. Boulders in foreground are residue from the Pleistocene Mesa Conglomerates.

b. La Venta badlands. Mesas in left and center lie along the western limit of the mapped area. The mesas are capped with Pleistocene Mesa Conglomerate. Front range of the Cordillera Central is seen in the background.



a

b

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